Exhibit D

Part 3

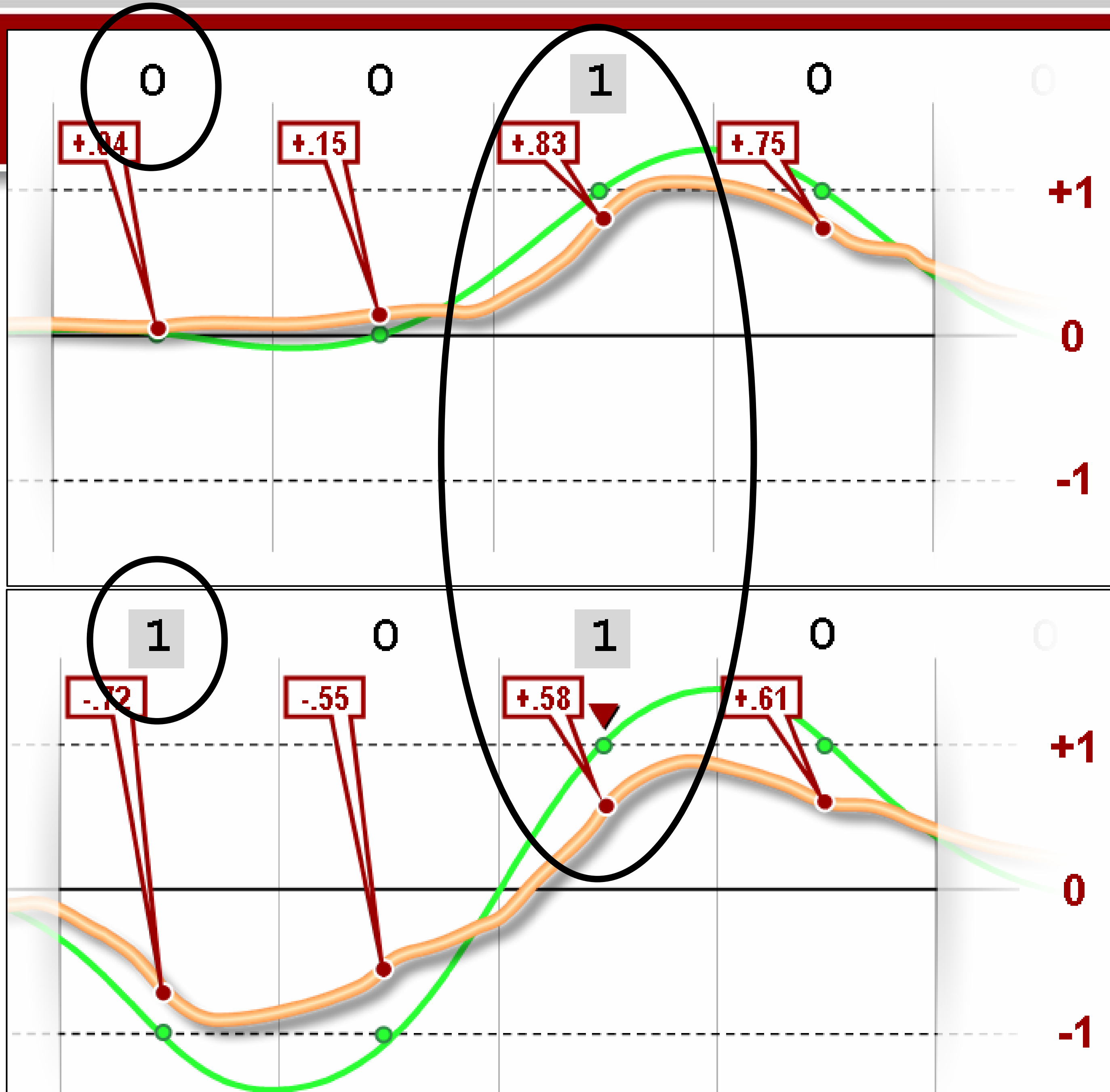
“Signal-Dependent” Terms

- Marvell’s Opening Claim Construction Brief supports CMU’s construction
  - Marvell equates “signal-dependent noise” with “data dependent noise”

> By the early 1990s, researchers had developed detectors to account for the effects of “signal-dependent” noise. *See* ’839 patent at 1:41-51. For example, in 1992, Prof. Cioffi at Stanford published a paper setting forth a modified Viterbi detector to “cope with **data-dependent noise.**” I. Lee & J.M. Cioffi, *Performance Analysis of the Modified Maximum*

Marvell’s Opening Claim Construction Brief at pg. 3.

  - The “data” are the written symbols recorded on the disk


0
0
1
0
+.04
+.15
+.83
+.75
+1
0
-1
1
0
1
0
-.72
-.55
+.58
+.61
+1
0
-1

“Signal-Dependent” Terms

- Marvell’s Opening Claim Construction Brief supports CMU’s construction
  - Assembling Marvell’s admissions, shows that “signal-dependent noise” is noise that is dependent on the particular pattern of data (e.g., symbols) written on the disk

CMU’s PROPOSED CONSTRUCTION

“Signal-dependent noise” means “media noise in the readback signal whose noise structure is attributable to a specific sequence of symbols (*e.g.*, written symbols).”

’839 Patent at col. 1:38-51; col. 2:9-20; col. 4:24-27; col. 5:48-54; col. 10:18-19.

The Viterbi algorithm and modifications to the algorithm became more prominent in the magnetic storage field as it shifted towards newer magnetic media and higher storage densities which suffered from increase noise. *See, e.g.*, R.W. Wood & D.A. Petersen, *Viterbi Detection of Class IV Partial Response on a Magnetic Recording Channel*, IEEE Trans. Commun. 454 (1986) (Exh. 5); H.K. Thapar & A.M. Patel, *A Class of Partial Response Systems for Increasing Storage Density in Magnetic Recording*, IEEE Trans. Magn. 3666 (1987) (Exh. 6); *see also* '839 patent at

Stanford published a paper setting forth a modified Viterbi detector to "cope with **data-dependent noise**." I. Lee & J.M. Cioffi, *Performance Analysis of the Modified Maximum Likelihood Sequence Detector in the Presence of Data-dependent Noise*, Proc. 26th Asilomar Conference 961, 961 (1992) (emphasis added) (Exh. 9). Also in 1992, Prof. Moon at the University of Minnesota, published a paper describing a detection scheme which "incorporate[s] the **data-dependent** nature of jitter **noise**." W. Zeng & J. Moon, *Modified Viterbi Algorithm for a Jitter-Dominant 1-D^2 Channel*, IEEE Trans. Magn. 2895 (1992) (emphasis added) (Exh. 10); *see also* W. Zeng, *Effective Detection Schemes for Magnetic Recording Channels with Severe Nonlinearities and Media Noise*, Ph.D. Thesis, at Abstract (1994) (introducing a detection

see also W. Zeng, *Effective Detection Schemes for Magnetic Recording Channels with Severe Nonlinearities and Media Noise*, Ph.D. Thesis, at Abstract (1994) (introducing a detection

scheme that "uses a **data dependent** error metric to include the effects of the **media noise**.") (emphasis added) (Exh. 11).

scheme that "uses a **data dependent** error metric to include the effects of the **media noise**.") (emphasis added) (Exh. 11).

By the mid-1990s, researchers had also developed detectors to account for "correlated" noise. For example, in 1995, disk-drive leader Seagate filed a patent application entitled, *Modified Viterbi Detector Which Accounts for* ***Correlated Noise***. U.S. Patent No. 6,282,251

B. Basic Statistics

The Viterbi algorithm and other methods to account for noise require knowledge of basic statistics, and a background in the relevant mathematics will help the Court to understand the asserted patents. The asserted claims contain several mathematical terms, such as correlation, covariance, and matrices. The patents also use several other mathematical terms, such as mean, variance, sum, and product. This section will briefly explain each of these statistics.

“Signal-Dependent” Terms

- Marvell ignores every reference to the phrase “signal dependent” found in the specification
    - Marvell’s claim construction argument is now premised on two extrinsic references and by a misreading of the claims
        - Although resorting to extrinsic evidence in its Surreply, Marvell ignores all of the prior art references to “signal-dependent noise” included in its opening brief

“Signal-Dependent” Terms

- Marvell’s reliance on, e.g. claims 2-5 of the ’839 Patent is misplaced and begs the question of what the term “signal-dependent noise” means
  - Marvell conveniently omits the fact that, e.g. claims 1 and 4 of the ’839 Patent do not require “signal-dependent noise”

’839 Patent

1. A method of determining branch metric values for branches of a trellis for a Virterbi-like detector, comprising:
   selecting a branch metric function for each of the branches at a certain time index; and
   applying each of said selected functions to a plurality of signal samples to determine the metric value corresponding to the branch for which the applied branch metric function was selected, wherein each sample corresponds to a different sampling time instant.

2. The method of claim 1 further comprising the step of receiving said signal samples, said signal samples having signal-dependent noise, correlated noise, or both signal-dependent and correlated noise associated therewith.

3. The method of claim 1 wherein said branch metric functions for each of the branches are selected from a set of signal-dependent branch metric functions.

4. A method of determining branch metric values for branches of a trellis for a Viterbi-like detector, comprising:
   selecting a branch metric function for each of the branches at a certain time index from a set of signal-dependent branch metric functions; and
   applying each of said selected functions to a plurality of signal samples to determine the metric value corresponding to the branch for which the applied branch metric function was selected, wherein each sample corresponds to a different sampling time instant.

5. The method of claim 4 further comprising the step of receiving said signal samples, said signal samples having signal-dependent noise, correlated noise, or both signal-dependent and correlated noise associated therewith.

’839 Patent at cols. 13:61-14:23.

“Signal-Dependent” Terms

- Marvell’s constructions for these terms are illogical
  - Marvell’s construction for “Signal-Dependent Branch Metric Function”
    - A branch metric function that accounts for “signal-dependent noise”
  - Marvell’s construction for “Signal-Dependent Noise”
    - Noise that ***is dependent on*** the signal

"Signal-Dependent" Terms

- Marvell's constructions for these terms are illogical
  - Marvell admits in its brief that "several claims … describe signal samples ***with*** signal dependent noise"

> Several claims of the asserted patents describe signal samples with signal-dependent noise. '839 patent at claim 2, 5, 18; '180 patent at claim 1, 8. A plain reading of these claims would define "signal-dependent noise" as simply "noise that is dependent on the signal."[22] The

Marvell's Opening Claim Construction Brief at pg. 34.

  - Claim 2 of the '839 Patent provides an example:

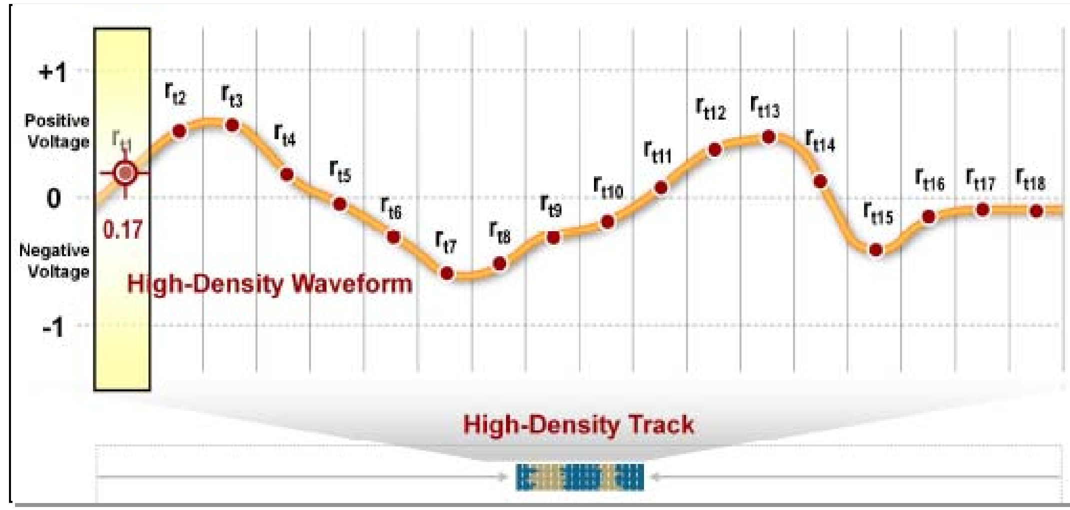
'839 Patent

> 2. The method of claim 1 further comprising the step of receiving said signal samples, said signal samples having signal-dependent noise, correlated noise, or both signal-dependent and correlated noise associated therewith.

'839 Patent at col. 14:3-6.

“Signal-Dependent” Terms

- Marvell’s constructions for these terms are illogical
  - The “signal samples” of the claims are from a “signal” (e.g. the readback signal)



  - Marvell’s construction means that the signal samples
    - **“hav[e]**…” signal dependent noise; ***and***
    - **“depend on”** signal dependent noise
  - Marvell’s construction is akin to saying that the noise ***in*** the signal samples ***is also dependent on*** the signal samples.

“Signal-Dependent” Terms

- CMU’s proposed construction was confirmed by Dr. Moura in response to Marvell’s deposition questions:

> Q. (Mr. Radulescu). What is your understanding of what signal dependence means in the context of magnetic recorders?
>
> MR. GREENSWAG: Objection, asked and answered.
>
> A. (Prof. Moura) So if I go back to the context of our patent, I know how to answer your question.
>
> Q. (Mr. Radulescu). Okay. Please do.
>
> A. (Prof. Moura) Okay. In the context of our patent, what we mean by signal dependence is dependence on the pattern, on the ***recorded pattern*****.** (emphasis added)

Moura Testimony at pg. 43:10-20. (Unofficial transcript)

The “Viterbi Algorithm” Term

Viterbi Algorithm

DISPUTED CLAIM TERMS

Viterbi Algorithm

’839 Patent Claims 1, 4, 11, 16, 19, 23

CMU’s PROPOSED CONSTRUCTION	MARVELL’s PROPOSED CONSTRUCTION
“Viterbi algorithm” means “an iterative algorithm that uses a trellis to determine the best sequence of hidden states (in this case, written symbols) based on observed events (in this case, observed readings that represent the written symbols), where the determined sequence is indicated by the best path through the trellis.”	**“Viterbi Algorithm” means “an algorithm that uses a trellis to perform sequence detection by calculating branch metrics for each branch of the trellis, comparing the accumulated branch metrics for extensions of retained paths leading to each node of the trellis at a given time, and for each node, retaining only the path having the best accumulated metric.”**
’839 Patent at col. 1:24-37; col. 2:49-50; col. 7:5-10; col. 10:26-52; Figs. 4-5; ’839 File History, March 10, 2000 Office Action and Response thereto. Plaintiff Carnegie Mellon University’s Claim Construction Reply Brief at pp. 9-10, n. 13.	’839 Patent, at cols. 1 and 5. ’839 File History, March 10, 2000 Office Action and Response thereto; Cited Art, including U.S. Patent Nos. 5,784,415; 5,781,590; 5,689,532; 5,920,599; 5,914,988.

Viterbi Algorithm

- Why construing this term matters
  - UNCLEAR – this is ***not*** a claim term
    - Critical question is whether in the face of the intrinsic evidence Marvell intends to assert that a “Viterbi-like” detector must compute a branch metric for each and every branch of each state of the trellis
    - While the Federal Circuit has made it clear that this Court can construe claims throughout the case, *O2 Micro Int’l Ltd. V. Beyond Innovation Tech. Co.*, 521 F.3d 1351, 1360 (Fed. Cir. 2008), we would like to avoid the disruption of a piecemeal construction
  - CMU is entitled to know now whether Marvell intends to raise an issue concerning whether a “Viterbi-like” detector must compute a branch metric value for each and every branch of each state of a Viterbi trellis

Viterbi Algorithm

- Why construing this term matters
  - In its tutorial, Marvell seems to be shifting positions
  - The parties' competing constructions are for the term "Viterbi algorithm"
  - Marvell's technology tutorial creates the impression that the Court is being asked to construe the term "Viterbi" without any mention of the ***<u>"-like"</u>*** component of this term

Group II: '839 Patent Claim 16

16. A method of detecting a sequence that exploits the correlation between adjacent signal samples for adaptively detecting a sequence of symbols through a communications channel having intersymbol interference, comprising the steps of:

(a) performing a Viterbi-like sequence detection on a plurality of signal samples using a plurality of correlation sensitive branch metrics;

(b) outputting a delayed decision on the transmitted symbol;

(c) outputting a delayed signal sample;

(d) adaptively updating a plurality of noise covariance matrices in response to said delayed signal samples and said delayed decisions;

(e) recalculating said plurality of correlation-sensitive branch metrics from said noise covariance matrices using subsequent signal samples; and

(f) repeating steps (a)-(e) for every new signal sample.

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Group I: '839 Patent Claim 4

4. A method of determining branch metric values for branches of a trellis for a Viterbi-like detector, comprising:

[1] selecting a branch metric function for each of the branches at a certain time index from a set of signal-dependent branch metric functions; and

[2] applying each of said selected functions to a plurality of signal samples to determine the metric value corresponding to the branch for which the applied branch metric function was selected,

wherein each sample corresponds to a different sampling time instant.

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Marvell's Technology Tutorial, slides 91, 96.

Viterbi Algorithm

- "Viterbi Algorithm" ***NEVER*** appears in the claims
  - The claim term is "Viterbi-like" (*see*, *e.g.* claim 1)

> 1. A method of determining branch metric values for branches of a trellis for a Virterbi-like detector, comprising:

'839 Patent at col. 13:61-62.

  - The parties stipulated to a construction for this term

Viterbi-like	839 cls. 1, 4, 11, 16, 19, 23	"Viterbi-like" means "similar to and including the 'Viterbi algorithm.'"

Joint Agreed and Disputed Claim Terms, Ex. A at pg. 3.

  - This term only appears in the specification in the title to a piece of prior art

> OTHER PUBLICATIONS
>
> Zeng et al., "Modified Viterbi Algorithm for Jitter–dominant 1–D^2 Channel," IEEE Trans. On Magnetics, vol. 28, No. 5, pp. 2895–97, Sep. 1992.

'839 Patent at pg 1.

Viterbi Algorithm

- CMU's construction for Viterbi algorithm is correct
  - There is one definition of this term in the "intrinsic evidence" found in the Fitzpatrick '532 Patent

'532 Patent

> The standard approach to implementing a Viterbi detector is to use the Viterbi algorithm to minimize the squared Euclidean distance between the sequence of noisy samples and all possible sequences of noiseless samples. The Viterbi algorithm is an iterative algorithm for determining the minimum metric path through a trellis, where the metric in this case is the squared Euclidean distance. During each

'532 Patent at col. 2:32-37.

Viterbi Algorithm

- Marvell also relies on the Fitzpatrick ’532 Patent, but is quoting from the “Detailed Description Of A Preferred Embodiment”
  - The portion of Fitzpatrick relied upon by Marvell is Fitzpatrick’s particular implementation of a Viterbi algorithm, not a general definition.

’532 Patent

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

distributed Gaussian noise with zero mean. The Viterbi algorithm is an iterative process of keeping track of the path with the smallest accumulated metric leading to each state in the trellis. The metrics of all of the paths leading into a particular state are calculated and compared. Then, the path with the smallest metric is selected as the survivor path. In this manner all paths which can not be part of the minimum metric path through the trellis are systematically eliminated.

’532 Patent at cols. 7:33-34; 7:64-8:4.

Viterbi Algorithm

- CMU's definition comes from the section of the Fitzpatrick '532 Patent that discusses several types of Viterbi detectors, ***including detectors that use a reduced state trellis relative to the "standard approach"***
  - "The Fitzpatrick '532 Patent discusses the "***standard approach*** to implementing a Viterbi detector…"
  - Marvell ignores this language in its brief and supporting citations

'532 Patent

The standard approach to implementing a Viterbi detector is to use the Viterbi algorithm to minimize the squared Euclidean distance between the sequence of noisy samples and all possible sequences of noiseless samples. The Viterbi algorithm is an iterative algorithm for determining the minimum metric path through a trellis, where the metric in this case is the squared Euclidean distance. During each clock cycle, an EPR4 Viterbi detector updates eight state metrics and selects one survivor path for each of the eight states. The survivor path represents the minimum metric path leading to a particular state, and the state metric represents the metric associated with that survivor path. In order to update the eight state metrics, the detector extends the survivor paths to obtain two paths to each state in the next trellis depth. A path metric is obtained by adding a state metric to a branch metric, where the branch metric represents the squared Euclidean distance between the current noisy sample and the noiseless sample associated with the branch. The path metrics associated with the two paths entering each state are compared and the minimum metric path is selected as the survivor path, and the path metric for this bath is selected as the new state metric. During each clock cycle, sixteen path metrics are calculated and eight comparisons are performed.

'532 Patent at col. 2:32-55.

Viterbi Algorithm

- CMU’s definition comes from the section of the Fitzpatrick ’532 Patent that discusses several types of Viterbi detectors, ***including reduced state detectors***
  - The Fitzpatrick ’532 Patent discusses a Viterbi algorithm that works with “eight states”

’532 Patent

or the ideal EPR4 samples. The EPR4 channel has eight states corresponding to the eight possible values of the last three binary input symbols, s[n]={x[n–3], x[n–2], x[n–1]}. The state transition diagram for the EPR4 channel shows the channel output symbol and the next state associated with all possible combinations of the binary input symbol and the state. The trellis diagram is obtained by adding a time axis

’532 Patent at col. 2:18:24.

Viterbi Algorithm

- CMU's definition comes from the section of the Fitzpatrick '532 Patent that discusses several types of Viterbi detectors, ***including reduced state detectors***
  - The Fitzpatrick '532 Patent also discusses a reduced state Viterbi (one that works with only four (4) states) meaning fewer branch metrics are calculated relative to the "standard" approach

'532 Patent

> One way of reducing complexity of an EPR4 Viterbi detector is to use decision feedback to subtract out the last trailing interfering symbol. Using this approach, the number of states in the trellis reduces to four corresponding to the two remaining interfering symbols. The EPR4 equalized

'532 Patent at col. 3:13-17.

As per claims 1, 4, 27-29, Fitzpatrick discloses a method for determining branch metric values for branches of trellis for a Viterbi-like detector (see figs.1, 2, 4) comprising: selecting a branch metric function for each of the branches at a certain time index (see col.2, lines 10-67 and

As per claims 6, 10 a method for generating a signal-dependent branch weight for branches of a trellis for a VITERBI-like detector (see figs. 1, 2, 4, 7) comprising: selecting a

As per claim 3, the system of Fitzpatrick inherently includes a branch metric function.

As per claims 6, 10 a method for generating a signal-dependent branch weight for branches of a trellis for a VITERBI-like detector (see figs. 1, 2, 4, 7) comprising: selecting a plurality of signal samples (see col.2, lines 10-67); calculating a first value representing a branch-dependent joint probability density function of a subset of said signal samples (see col.4, lines 5-67 and col.5, lines 15-40 and col.6, lines 40-55 and col.7, lines 55-67 and col.8, lines 1-21 and col.11, lines 55-67 and col.14, lines 10-67); calculating a second value representing a branch-dependent joint probability density function of a subset of said signal samples (see col.4, lines 5-67 and col.5, lines 15-40 and col.6, lines 40-55 and col.7, lines 55-67 and col.8, lines 1-21 and col.11, lines 55-67 and col.14, lines 10-67); calculating the branch weight from said first and second values (see col.4, lines 5-67 and col.5, lines 15-40 and col.6, lines 40-55 and col.7, lines

Viterbi Algorithm

United States Patent [19] **Fitzpatrick**

[11] **Patent Number:** **5,689,532**
[45] **Date of Patent:** ***Nov. 18, 1997**

[54] **REDUCED COMPLEXITY EPR4 POST-PROCESSOR FOR SAMPLED DATA DETECTION**

[75] Inventor: **Kelly K. Fitzpatrick**, Mountain View, Calif.

Wood, "Turbo–PRML: A Compromise EPRML Detector", *IEEE Transactions of Magnetics*, vol. 29, No. 6, Nov. 1993.

Forney, "The Viterbi Algorithm", *Proceeding, of the IEEE*, vol. 61, No. 3, Mar. 1973, pp. 268–2278.

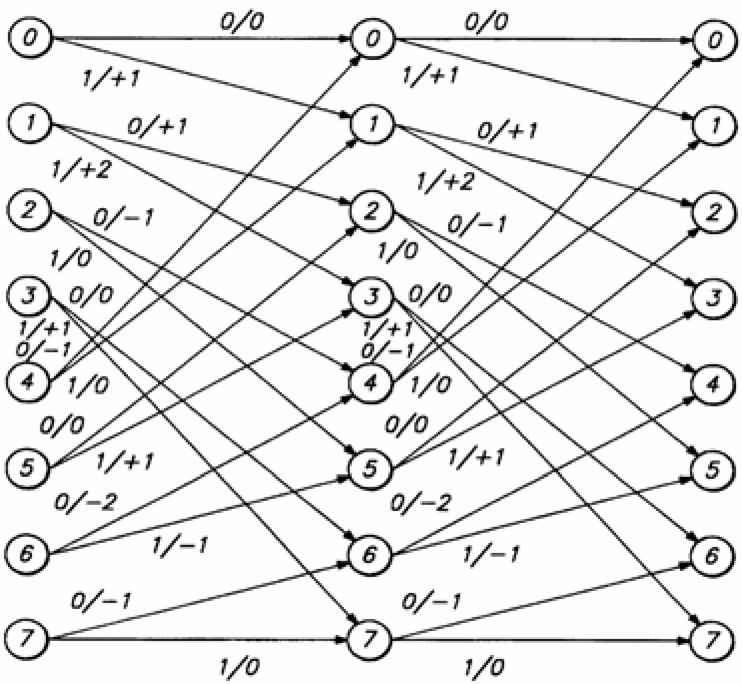

FIG. 4

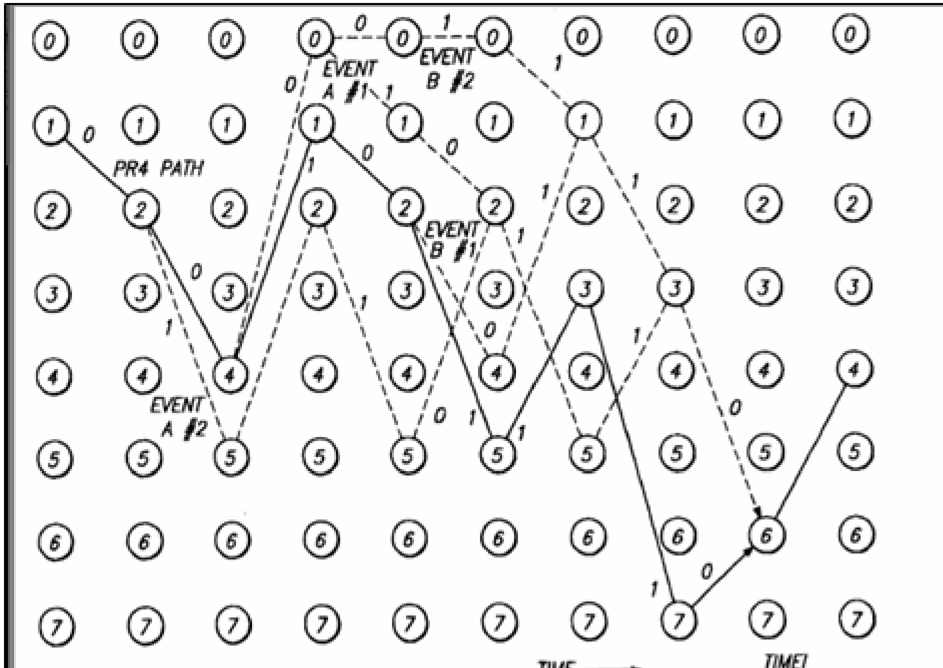

FIG. 7

function for each of the branches at a certain time index…; applying said selected function to a plurality of time variant signal samples to determine the metric values (see col. 2, lines 32-67 and col. 5, lines 45-67 and col. 7, lines 35-55 and col. 8, lines 1-22)." Applicants submit that Fitzpatrick does not teach all of the elements independent claims 1, 4, 6, 10, 27, and 28 and, thus, those claims are not anticipated by Fitzpatrick.

Applicants have herein amended claims 1, 4, 27, and 28 to clarify that each of said selected functions is applied to a plurality of signal samples to determine the metric value corresponding to the branch for which the applied branch metric function was selected, wherein each sample corresponds to a different sampling time instant. Applicants submit that Fitzpatrick does not teach, among other steps, such a step. In particular, each of the branch metrics is not determined based on a plurality of signal samples.

Fitzpatrick does not specify the manner in which the branch metrics are computed. However, the Viterbi detector described in Fitzpatrick is described as an EPR4 Viterbi detector. Such a Viterbi detector computes a branch metric using:

$$\mathcal{M}_i(r_i, a_{i-3}, \ldots, a_i) = [r_i - y(a_{i-3}, \ldots, a_i)]^2$$

where r_i is a single waveform sample, not a plurality of time variant signal samples. Thus, because Fitzpatrick does not teach every step of claims 1, 4, 27, and 28, Applicants submit that claims 1, 4, 27, and 28 are not anticipated by Fitzpatrick. Also, Applicants submit that because claims 1 and 4 are not anticipated by Fitzpatrick, claims 2 and 3 and 5, which depend therefrom, respectively, are not anticipated by Fitzpatrick.

Independent claims 6 and 10, as amended, both recite the step of selecting a plurality of signal samples, wherein each sample corresponds to a different sampling time

instant. As discussed hereinabove in connection with claims 1, 4, and 27-29, Fitzpatrick does not teach such a step. Thus, Applicants submit that independent claims 6 and 10, and dependent claims 7-9 which depend from claim 6, are not anticipated by Fitzpatrick.

The Examiner rejected claims 11-22 as being anticipated by U.S. Patent No. 5,862,192 to Huszar et al. The Examiner stated that Huszar et al. "discloses a method for detecting a sequence that exploits the correlation between adjacent signal samples for adaptively detecting a sequence of symbols stored on a high density magnetic recording device comprising the steps of: performing a Viterbi-like sequence detection…on a plurality of signal samples using a plurality of correlation sensitive branches…" Applicants submit that Huszar et al. does not teach all of the elements in independent claims 11, 16, 19, and 20 and, thus, those claims are not anticipated by Huszar et al.

Independent claims 11 and 16 both recite the step of "performing a Virterbi-like sequence detection on a plurality of signal samples using a plurality of correlation sensitive branch metrics." Independent claim 19 recites, as an element, "a correlation-sensitive metric computation update circuit responsive to said noise statistics tracker circuit for recalculating a plurality of correlation-sensitive branch metrics from said noise covariance matrices, said branch metrics output to said Viterbi-like detector circuit." Applicants submit that Huszar et al. does not show such a step or an element.

Huszar et al. discloses branch metrics that are not correlation sensitive. Instead, the branch metrics of Huszar et al. are path metrics that have the form of (*See* Huszar et al., col. 8, equation 17):

$$J = \sum_{\text{from } i=-\infty \text{ to } \infty} \mathcal{M}_i$$

Viterbi Algorithm

- The unrebutted evidence makes clear that the invention of the CMU patents is intended to work with all forms of Viterbi sequence detection systems, including those that compute branch metrics for fewer than all of the states of the trellis

’839 Patent

> In the derivations of the branch metrics (8), (10) and (13), no assumptions were made on the exact Viterbi-type architecture, that is, the metrics can be applied to any Viterbi-type algorithm such as PRML, FDTS/DF, RAM-RSE, or, MDFE.

’839 Patent at col. 7:5-9.

> 32. Forney’s paper describes that each branch of the trellis is assigned a “length” (or value). However, in the early to mid-1970s, digital circuits often did not have the processing power to compute a branch length (or value) for each branch of the trellis in a sufficiently timely manner for certain applications. Accordingly, subsequent to Forney’s paper, engineers developed Viterbi detectors where the branch metric calculations were carried out on fewer than all of the branches of a Viterbi trellis.

McLaughlin Declaration, 1/27/10, at pg. 10.

Viterbi Algorithm

- Because “Viterbi-like” sequence detection does not require computing a branch metric for “each” branch for each state of the trellis, having a construction for “Viterbi algorithm” that includes that limitation will only create confusion